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THIRTEEN YEARS OF WHEAT SELECTION

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Introduction

In 1901 the Minnesota Agricultural Experiment Station planted a number of varieties of wheat from the *polonicum, spelta, turgidum, durum* and *vulgare* types in foundation beds in order to have specimens of these different types always on hand for class work, hybridization or demonstration purposes. Six of these varieties—hedgrow (*turgidum*), Russian (*vulgare*), common speltz (*spelta*), kamouka (*durum*), and Polish (1) and Polish (2) (varieties of *polonicum*)—have been grown continuously since that time and an effort has been made to improve them by selection. The method followed was that introduced at this station by Professor W. M. Hays and called the "centgener" method.

The centgener method consists, briefly, in starting with individual plants, planting one hundred selected kernels from each plant at equal depths and at equal distances apart in separate plots. A plot of one hundred plants is called a centgener. Careful notes are taken on the plants in each centgener and at harvest time five or more of the highest yielding plants are selected from which the seeds for planting the next year are taken. From these five best plants from five to ten of the best heads are selected and thrashed together. One hundred of the largest and plumpest kernels are then selected out of the seed obtained by thrashing these selected heads, and these are planted in the centgener test the next year. This work is continued from year to year, each season the hundred best kernels from the five or more best plants being planted in succeeding centgeners.

In 1908 an experiment was planned with the object of developing a strain of wheat which would have a minimum amount of culm exposed between the base of the spike and the upper leaf sheath, or in other words, to produce a short-necked variety of wheat. The ultimate purpose of reducing the neck lengths was to reduce the area of the stem exposed to the black stem rust. Since this rust ordinarily does little damage to that portion of the culm enclosed in the leaf sheath, it was thought that a short-necked wheat would be more likely to escape serious damage from stem rust than a long-necked kind. For this work individual plants were selected which had short necks and the seed from these were planted in separate centgeners. Each year at harvest time ten or more plants which appeared to the observer to have the shortest necks were selected from each centgener and measurements of their neck lengths were made and recorded. One hundred kernels were saved from these shortest necked plants each season for subsequent centgeners, thus making a continuous selection for short neck lengths.

The data derived from the above experiments seems to throw some light upon the much-discussed question as to whether or not selection within a pure line can increase yield or change type enough to make it a desirable practise from the practical breeder's standpoint. In both of the experiments, we have the requirements for a pure line satisfied. Wheat is a normally self-fertilized plant. Each centgener was started from a single head in 1901 and these heads have bred true to type ever since.

The long period of years over which this experiment has extended makes the data particularly valuable. One of the adverse criticisms to most pure line work is that it has not extended over a long enough period of time. Thirteen years are about as long as any practical breeder would be apt to keep up selection on one pure line and covers the longest period of continuous selection for a self-fertilized plant yet reported.

Another criticism to pure line investigations is that in many cases it has not appeared certain that the material studied was a pure line. Since the plants have bred true to type throughout the whole period of study, it is obvious that this criticism will not hold for the data herein presented.

The work has been conducted at this station under the direction of Professor W. M. Hays from 1901 to 1905, under Professor E. C. Parker 1905 to 1908, under Professor Andrew Boss from 1908 to 1911 and under Professor C. P. Bull 1911 to 1913.

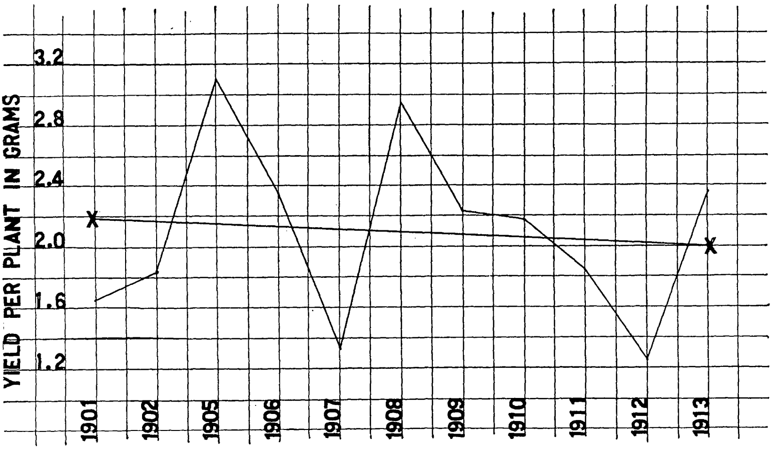

PLATE I. Average yield per plant for all varieties. X–X, fitted straight line.

SELECTION TO INCREASE YIELD

The varieties studied, the average annual yield of each variety and the average yield per plant for the six varieties under test are shown in Table I. In the years 1903 and 1904 weather conditions were unfavorable, making it impracticable to obtain correct average yields per plant, so data for these years were omitted. However, selections of the best plants were made in these two seasons as in the others and the best seed from them were kept for planting, so the continuous selection for increased yield was uninterrupted.

TABLE I

SHOWING YIELD PER PLANT—YEARS 1901–1913

Name of Variety	Yield per Plant in Grs.										
	1901	1902	1905	1906	1907	1908	1909	1910	1911	1912	1913
Hedgrow	3.10	2.80	3.69	2.48	1.27	3.75	2.49	2.55	2.02	.99	3.67
Russian	1.00	1.70	3.57	1.96	1.71	2.74	2.71	2.17	1.95	1.37	2.70
Speltz	2.40	1.80	3.99	2.99	1.38	3.38	2.40	2.86	2.01	2.14	2.59
Kamouka	1.50	2.50	1.99	2.69	1.39	3.31	2.19	2.48	1.67	1.35	2.16
Polish (1)	.80	1.30	2.52	2.04	1.03	1.48	1.91	1.70	1.56	1.12	1.74
Polish (2)	1.10	.95	2.83	1.97	1.26	....	1.61	1.31	1.78	.51	1.33
Average	1.65	1.84	3.10	2.35	1.34	2.93	2.22	2.18	1.83	1.24	2.36

SELECTION TO INCREASE HEIGHT

The average height of the plants for each year of the test is shown in Table II. Though no attempt was made to select for increased height, since a number of workers have shown that height in the small grains is distinctly correlated with yield, it is natural to suppose that the selected plants were among the tallest as well as being the highest yielders of each year's crop. When this experiment was begun, it was not known that height and yield were correlated, so the figures on height were kept merely as a matter of general interest and with no idea that they would have bearing on the problem. Among those who later found height correlated with yield are Deneumostier ('10),[1] Love ('11),[2] Myers ('12),[3] Leighty ('12)[4] and

TABLE II

SHOWING AVERAGE HEIGHT PER PLANT—1901–1913

Name of Variety	Height in Inches									
	1901	1902	1905	1906	1908	1909	1910	1911	1912	1913
Hedgrow	36	41	42	43	46	41	38	41	36	36
Russian	34	37	40	35	44	41	33	36	35	32
Speltz	34	38	37	47	44	41	39	42	39	35
Kamouka	36	34	34	38	40	40	32	38	36	33
Polish (1)	40	38	41	38	42	42	33	39	38	33
Polish (2)	28	30	37	37	.....	35	31	38	31	32
Average	35	36	38	39	43	40	34	39	36	33

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[1] Deneumostier, C., "Correlations in Wheat," *Ann. Gembloux,* 20, No. 5, 1910.

Selection to Decrease Neck-Lengths

The result of the selection for short neck-lengths is shown in Table III. This is a clear illustration of how misleading short-term experiments may be. Had the experiment been discontinued at the end of the third year, the figures would have indicated that it was possible to modify this character very rapidly by selection. However, in the following two years the neck-lengths seemed to revert to the mean of the pure lines, and the last year they were actually longer than when the experiment was started. The reduction in the first three years was probably due to growing conditions.

TABLE III

Showing Result of Selection for Short Necks

	Average Neck Length in Curve				
	1909	1910	1911	1912	1913
Series *A*	7.4	1.86	.24	7.34	9.54
Series *B*	6.1	1.12	.79	8.13	11.6
Series *C*	5.8	1.65	.56	7.53	8.21
Series *D*	5.2	2.08	.59	10.47	13.82

Discussion

From the data presented in these tables, it is evident that there has been no permanent gain for these thirteen years of selection either in yield per plant, height of plant, or shortening of neck-lengths. The expected seasonal variations occur. A comparison of the yield of Haynes Blue Stem, which is grown extensively in Minnesota, and was continued in the variety test without any attempt at selection throughout the whole period, with Hutcheson ('13).[5]

[2] Love, H. H., "A Study of the Large and Small Grain Question," *An. Rep. Am. Br. Asso.,* 7: 109–118, 1911.

[3] Myers, C. H., "Variation, Correlation and Inheritance of Characters of Wheat and Peas," Cornell University Thesis, 1912.

[4] Hutcheson, T. B., "Correlated Characters in *Avena sativa,* with Special Reference to Size of Seed Planted," Cornell University Thesis, 1913.

[5] Leighty, C. E., "Studies in Variation and Correlation of Oats, *Avena sativa,*" Cornell University Thesis, 1912.

the average yield of the selected varieties, is shown in Table IV. The average yield in bushels of the Haynes Blue Stem is also platted in comparison with the average yield of the selected varieties in Plate II. In 1912 a severe hail storm injured the variety plats so much that it was thought best not to include the yield of the Haynes Blue Stem for that year. This gives an incorrect appearance to the curve, as it was extended just as if this year was present and midway between 1911 and 1913 in yield. It will be noticed from Table IV and Plate II that the

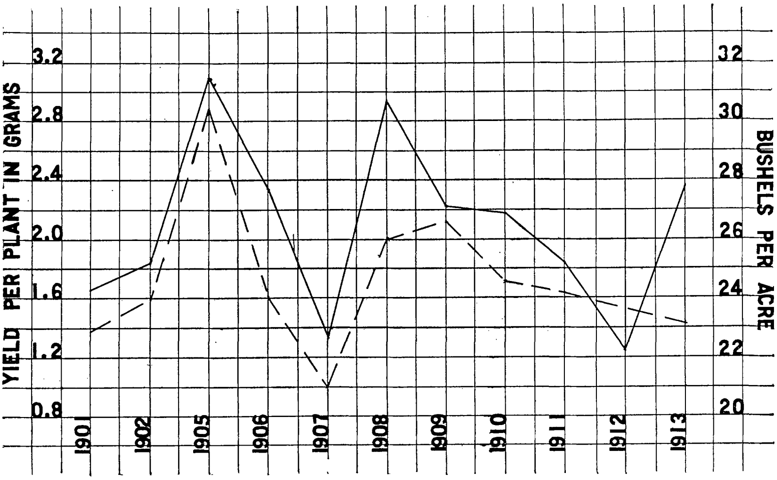

Plate II. Comparing seasonal fluctuations in selected lines with unselected Blue Stem. Solid line, yield per plant in grams for selected lines; dashed line, yield in bushels per acre for Blue Stem.

TABLE IV

Comparing Seasonal Fluctuations in Selected Lines with Unselected Blue Stem

	1901	1902	1905	1906	1907	1908	1909	1910	1911	1912	1913
Yield in grs. per plant for selected lines..........	1.65	1.84	3.10	2.35	1.34	2.93	2.22	2.18	1.83	1.24	2.36
Yield in bu. per acre for blue stem..........	22.9	23.9	30.4	24.00	21.00	26.00	26.6	24.6	24.2	.....	23.2

fluctuations from year to year agree very closely. These data indicate that increased yield is due to favorable environmental factors and not to improvement by selection.

A comparison of the yield of each variety for the first five years of the test with that of the last five years is shown in Table V. The data in this table show that there is no significant difference in yield for these two periods. In Russian and Polish (1) there is a slight increase in favor of the latter period, but in the other four varieties there is just as much decrease for this period. However, there is not enough difference in any case to indicate either permanent improvement or decrease in yield. As far as these varieties are concerned, it seems that selection has brought about no permanent improvement.

TABLE V

COMPARING THE YIELD OF THE FIRST-YEAR PERIOD WITH THAT OF THE LAST FIVE-YEAR PERIOD

Name of Variety	1st 5-year Period		Last 5-year Period	
	Height	Yield	Height	Yield
Hedgrow	41.6	2.67	38.4	2.34
Russian	38.0	1.99	35.4	2.18
Speltz	40.0	2.51	39.2	2.40
Kamouka	36.4	2.01	35.8	1.97
Polish (1)	39.8	1.54	37.4	1.61
Polish (2)	33.4	1.62	33.4	1.31
Average	38.2	2.06	36.5	1.97

A curve of the yields of the six varieties under consideration for the thirteen years of the test was plotted and a straight line was fitted to it, by the method of the least squares, to indicate the trend of the yield. This curve is shown in Plate I. There is a slight downward tendency in this straight line, but it is not enough to indicate a tendency toward decrease in yield. The line fitted to the curve of height (Plate III) also shows a slight tendency downward.

The data herein cited are not sufficient for definite conclusions. However, the indications are that from a practical breeder's standpoint permanent improvement in pure lines in small grains, if possible, is certainly not rapid or apt to be very marked. Thirteen years of selection covers considerable time and expense, and, as far as can be seen from the varieties reported in this paper, it has resulted in no permanent improvement. This would suggest that some other line of improvement must be sought. It is probable that much more rapid progress could be made by segregating pure lines from mixed populations and combining the desirable characters of these lines by hybridization.

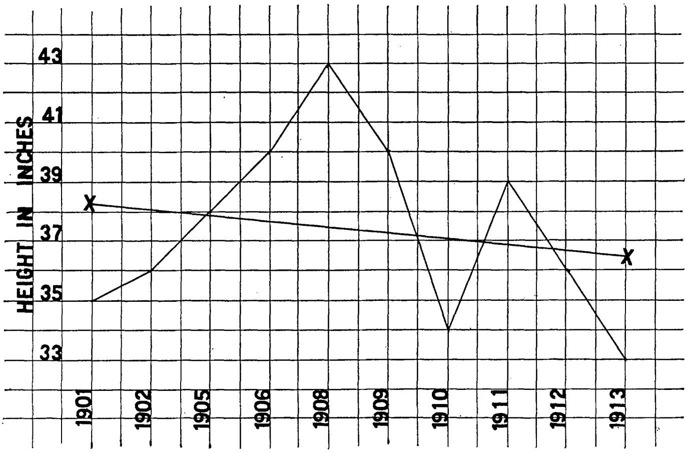

PLATE III. Average height of all varieties. X–X, fitted straight line.